



## Original Research Article

Where have all the falcons gone? Saker falcon (*falco cherrug*) exports in a global economyPaul B. Stretesky<sup>a,\*</sup>, Ruth E. McKie<sup>b</sup>, Michael J. Lynch<sup>c</sup>, Michael A. Long<sup>d</sup>, Kimberly L. Barrett<sup>e</sup><sup>a</sup> Department of Social Sciences, Northumbria University, Lipman Building, Newcastle Upon Tyne NE1 8ST, UK<sup>b</sup> Department of Social Sciences, De Montfort University Leicester, LE1 9BH, UK<sup>c</sup> Department of Criminology SOC107, University of South Florida, Tampa, FL 33620, USA<sup>d</sup> Murray Hall, Department of Sociology, Oklahoma State University, Stillwater, OK 74075, USA<sup>e</sup> Sociology, Anthropology, & Criminology Department, Eastern Michigan University, 712 Pray Harrold, Ypsilanti, MI 48197, USA

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## ABSTRACT

Within conservation biology growing evidence of the decline of the Saker falcon (*falco cherrug*) population has directed attention to the role of the global falcon trade. Here, we examine factors that may explain the global Saker trade using ecological modernization, treadmill of production and unequal ecological exchange as theoretical frameworks. We estimate trends in Saker exports using the most comprehensive measure available – Convention on International Trade in Endangered Species of Wild Fauna and Flora Trade Database. Our analysis employs fixed effects regression techniques to control for unobserved heterogeneity between nations to isolate the most important drivers of Saker exports. We find that the rise in Saker exports are partly correlated with a nation's increasing income and growing dependence on trade. Such a situation infers that the global Saker falcon population will continue to diminish if conservation policy does not change and current economic conditions continue.

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## 1. Introduction

The relationship between economic development and environmental conservation is well studied within sociology, often emphasizing treadmill of production, unequal ecological exchange or ecological modernization frameworks (Buttel, 2000; Fisher and Freudenburg, 2001; Gould et al., 2004; Schnaiberg, 1980; Spaargaren and Mol, 1992). However, these three frameworks have yet to be evaluated within a conservation biology perspective to examine wildlife trade. We address this omission by examining global exports of the Saker falcon (*falco cherrug*). Studies document a persistent decline in Saker populations in certain locations (Ragyov et al., 2014). Serious concern over the Saker falcon population decline has prompted a global response, and organizations such as the IUCN have changed the status of the falcon from 'near threatened' to 'endangered' on the Red List of Threatened Species (BirdLife, 2017). Saker exports are now regarded as one of the major threats to the species, impacting both its population numbers and geographic distribution (Chavko, 2010; Dixon et al., 2009; Levin,

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2011; Yi-Ming et al., 2000; Zahler et al., 2004). Thus, a better understanding of the variables impacting Saker exports is critical for conservation policy.

The purpose of this work is to assess the predictive capability of conservation efforts, ecological modernization, treadmill of production and unequal ecological exchange arguments, and provide a more complete understanding of national trends in the number of live Saker falcon exports. The legal exports of Saker falcons are recorded in the *Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Trade Database*, which is recognized as the most comprehensive source of wildlife trade available. The CITES database can be used to analyze trends in flows of wildlife trade that could lead to an over-exploitation of species and a loss of global biodiversity (Courchamp et al. 2006; Martin-Smith and Vincent, 2006). Our analysis of trade data represents the first comprehensive longitudinal examination of Saker falcon commodification.

Our analysis of Saker falcon exports is divided into five additional sections. First, we briefly outline our theoretical contribution to conservation biology through the study of declining populations. We use the concept of declining populations to lay the foundation for three human-environment frameworks: ecological modernization, treadmill of production and unequal ecological exchange. These frameworks are often emphasized in the study of environmental problems and provide us with a context for understanding the potential relationship between a nation's economic conditions and its willingness to export Saker falcons. Second, we provide a synopsis of the Saker falcon ecology, briefly cover conservation efforts and explain how we measure falcon exports. Third, we describe the key variables used to examine the three different theoretical frameworks that we believe may predict Saker exports within nations. Fourth, we use these key variables to predict exports within major exporting nations. Finally, we draw some conclusions about the role of conservation biology, ecological modernization, treadmill of production and unequal ecological exchange in explaining rising Saker exports and recommend a way forward for conservation efforts.

## 2. Theory

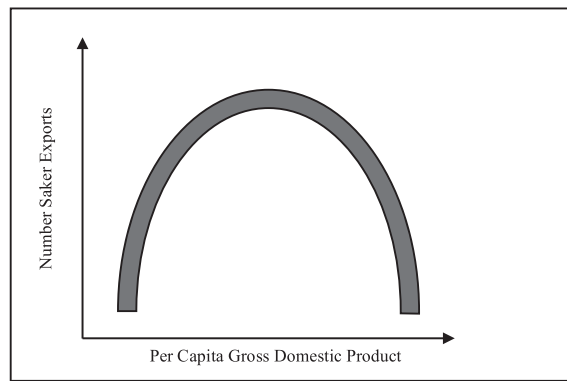
### 2.1. Conservation biology

In 1985 Michael Soulé described conservation biology as a young discipline that represents a new “application of science to conservation problems, addresses the biology of species, communities, and ecosystems that are perturbed, either directly or indirectly, by human activities or other agents” (Soulé, 1985, p.727, 732). Conservation biology is described as a “crisis discipline” as its scientists are often called upon to evaluate immediate problems experienced by wildlife populations and recommend quick solutions. Because of this tendency, conservation biology has sometimes been criticized for failing to use scientific methods and theories that examine species decline (Gaggiotti, 2001). Caughley (1994), for example, suggested that factors that lead to species extinction are not generalized or related back to theories and concepts that have been extensively tested within ecological disciplines. Thus, the crisis aspect of conservation biology produces “case-by-case ecological investigation and recording operation, often short on scientific rigor, that provides few opportunities for advancing our general understanding of the processes of extinction” (Caughley, 1994, p.215).

As conservation biology continued to develop it has resulted in two separate strands of scientific inquiry: (1) the small-population paradigm and (2) the declining-population paradigm (Caughley, 1994). The small-population paradigm is focused on determining how long a small population will last while the declining-population paradigm is concerned with factors that make large populations small. Caughley (1994, p.215) argued that a combination of both paradigms “might well lead to a reduction in the rate at which species are presently going extinct.” Our focus is on the declining-population paradigm as it centers on the way humans contribute to species decline over the long-term. Within the conservation biology approach, we emphasize its focus on the conservation solutions that protect species and their habitats, especially by examining the potential role macro-level policy (e.g., land conservation) plays in species conservation.

Our specific interest in the declining-population paradigm is to incorporate its overarching ideas about land use to show potential ways to expand the paradigm beyond case studies. We do this by drawing upon the well-established ecological footprint (Wackernagel and Rees, 1996) and the *World Database on Protected Areas (UNEP-WCMC, 2017)* to examine the Saker trade. To do so, we employ a global approach to falcon exports and a recognition that the commodification and export of falcons play a role in declining-populations. It is an approach that Salleh et al. (2015, p.99) describe as an ‘ecological imagination’ that links land use and conservation concerns (e.g., Foley et al., 2005, p.570–571; McKinney, 2002; McKinney et al., 2009; McKinney et al., 2010).

As noted, the conservation biology approach is focused on identifying and recommending policy efforts that protect species and their habitats. We focus on the relationship between national land use conservation efforts and trends in wildlife exports. Ideally, nations that do a better job safeguarding their natural capital and ecosystem services are likely to export more falcons. That is, scientific authorities that review export requests should be more likely to approve Saker exports when nations run successful wildlife conservation programs. The suggestion that conservation efforts lead to increased exports is, nevertheless, still speculative and may be too optimistic. For instance, research by Smith et al. (2003) suggests that financial aid dedicated to grow wildlife populations may have little impact in politically corrupt nations where it has a high probability of being redirected elsewhere. Unfortunately, then, in corrupt nations it is possible that scientific authorities will have less



**Fig. 1.** The theoretical impact of economic development on the saker trade.

knowledge about the true extent of conservation efforts and therefore make errors about Saker populations when approving exports.<sup>1</sup> Hence, we must acknowledge that any potential positive association between conservation efforts and Saker exports may be weakened by political corruption.

Specific national level indicators of Saker conservation do not exist across nations. However, there are general indicators of conservation that should theoretically increase wildlife populations. For instance, the percentage of a nation's legally protected lands is a global indicator of conservation efforts – one that should protect Saker habitats. Moreover, a decrease in the ecological footprint should increase wildlife populations and biodiversity. Thus, a decrease in the ecological footprint should lead to an increase in Saker falcons and therefore an increase in exports. Taken together, the conservation biology perspective leads us to propose:

**Hypothesis 1.** As a nation's conservation efforts increase, its Saker falcon exports will also increase.

## 2.2. Ecological modernization

Ecological modernization is based on the idea that economic development and environmental protection are related (Spaargaren and Mol, 1992). Early phases of economic development generate environmental harm; however, additional economic development can solve these problems. For example, in this case, development of Saker falcon lands encourages Saker captures, reducing their populations, while economic development creates wealth and knowledge that can be used to protect lands and habits, or to create Saker breeding farms and reduce Saker captures. As a framework, ecological modernization suggests that environmental protection is a luxury that can be afforded as development expands, and is therefore more likely to be supported in affluent societies (Gelissen, 2007). Thus, regulations protecting the environment will not emerge until enough wealth is obtained to support and pay for environmental protection efforts. As a nation's wealth increases, pressure to protect the environment comes from a variety of sources including the public, government and non-governmental organizations (Spaargaren and Mol, 1992). This type of reasoning has led some scholars to apply the Kuznets curve to environmental problems. The curve, developed by Simon Kuznets (1955), suggested that income inequality caused by economic development can be solved with more economic development. Applying that assumption to the development-environment interface, the environmental Kuznets curve Hypothesis suggests there is an inverted-U shape relationship between economic development and environmental harm, so that as development progresses, environmental harm declines (Selden and Song, 1994). Nevertheless, there is still some debate about the Kuznets curve (Gill et al., 2017; Lynch, 2016), and various scholars suggest that reductions in environmental harm may come from deindustrialization and the movement of manufacturing to developing nations (i.e., 'the race to the bottom', see Dasgupta et al., 2002). Following arguments in ecological modernization about the Kuznets curve we test for this type of relationship in the case of Saker falcon exports as hypothesized in Fig. 1.

Fig. 1 draws upon the Kuznets Hypothesis to diagram the theoretical relationship between national income levels and Saker falcon exports (Hollander, 2003). That hypothetical relationship would suggest that falcon exports increase as they generate income, level off for a time and then decrease when national income levels are relatively high and falcon trade can be viewed as cruel and/or harmful to conservation efforts. In the case of falcon exports, this inverted U-shaped relationship may have more to do with long term pressure to develop national regulations and policies that prevent all types of harm to endangered species. That is, efforts to employ legally created land conservation mechanisms to protect the Saker falcon (e.g., Turkmenistan and Romania) have sometimes been questioned (Gache, 2014). Within the modernization perspective this

<sup>1</sup> We thank the anonymous reviewer for identifying the potential indirect relationship between corruption and Saker exports that may occur through scientific authorities.

notion of more ecologically friendly laws is compatible with the idea that stakeholders will also pressure the government to engage in conservation activities that protect biodiversity. One such effort may be the pressure to reduce Saker exports. Nevertheless, many wealthy states have yet to promulgate regulations that prevent the commodification of falcons within their borders, including serious penalties for poaching, killing birds, destroying nests or harming habitats (e.g., Saudi Arabia).

A central argument in ecological modernization is that industry will become more ecologically rational over time because it benefits the economy (Spaargaren and Mol, 1992). That is, industry will balance ecological concerns with economic concerns. Sometimes this is described as generating 'green production' or 'greening the economy.' There is no doubt that some nations have adopted this approach to declining falcon populations. For instance, business entrepreneurs in Mongolia are taking advantage of the opportunity to create significant profit and promote conservation efforts by breeding Saker falcons to sell in the international marketplace. This policy has generated falcon exports that reportedly produced nearly \$3 million in revenue per year in Mongolia (Dixon et al., 2011, p. 368). Despite these unique examples, the deleterious impact of commodification on Sakers has occurred through capture and export. As the modernization perspective suggests, increasing national income should eventually give way to lower exports of endangered species as people have the wealth to resist the commodification of the environment for economic gain. Thus, the ecological modernization perspective leads us to hypothesize the following relationship summarized in Fig. 1:

**Hypothesis 2.** There is an inverted-U shaped relationship between a nation's income and Saker exports.

In our linear regression analysis, this inverted-U shaped relationship between income and exports is first tested using the conventional quadratic method (Lind and Mehlum, 2010). Thus, the analysis includes gross domestic product (which should be positively related to Saker exports) and the square of gross domestic product (which should be negatively related to Saker exports). At minimum, both relationships must be simultaneously observed and the estimated maximum data point must be within the range of the data for Hypothesis 2 to be supported.

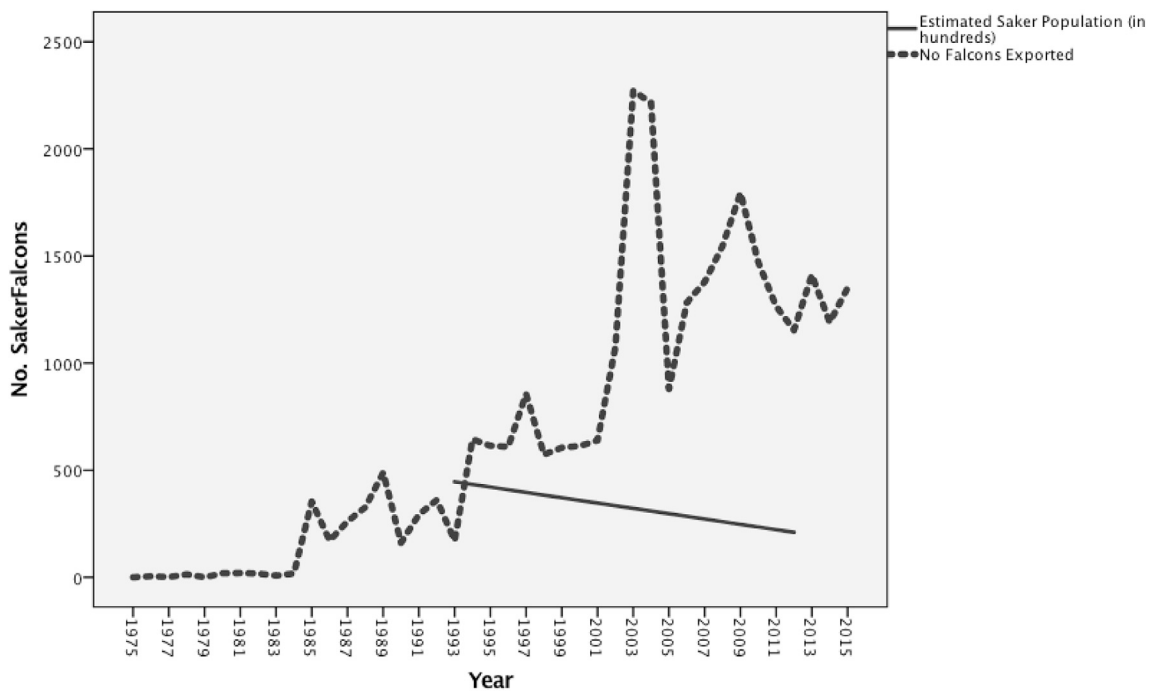
### 2.3. Treadmill of production & unequal ecological exchange

The 'treadmill of production' framework, first proposed by Schnaiberg (1980), refers to a political economic system characterized by the continued expansion or 'acceleration' of 'industrial production, economic development and increasing consumption' (Gould et al., 1996, p. 5). The treadmill economy is driven by the accumulation tendencies of capitalism, and enhanced by advancements in chemical technology that reduced production costs shortly after World War II. The surplus generated from chemical production were then reinvested in technology to expand production even further (Gould et al., 2004). Expansion of the treadmill also increases ecological withdrawals of materials from nature, and deposition of ecological additions or pollution.

Gould et al.'s (2004; 2008) treadmill of production framework illustrates how global capitalism can threaten biodiversity by (1) accelerating natural resource extraction (an ecological withdrawal) in a way that diminishes wildlife habitats and (2) increasing toxic releases (an ecological addition) in a way that poisons organisms and disrupts reproductive systems (e.g., egg shell thinning as with DDT [Shobrak, 2015]) and food chains (see also Freedman, 1995; Hassan et al., 2005). In the present study, we extend the treadmill of production framework to examine Saker exports as an outcome of natural resource extraction linked to its population decline. Consistent with the treadmill of production framework, we suggest that the production of falconry, which is currently maintained by falcon exports, takes priority over conservation efforts.<sup>2</sup> For instance, Shobrak (2015: 492) notes that in many areas of northern and central Asia Saker trapping for falconry "has become unsustainable." The withdrawal of raptors from their natural environment for the production of falconry leads to ecological disorganization. In particular, raptors help maintain species richness (Sekercioglu, 2006). Raptors are highly mobile and therefore able to limit rodent populations across large areas. Raptor hunting patterns are also thought to alter the foraging behavior of potential prey which may also help to balance ecosystems. In short, the withdrawal of Sakers and other raptors from the environment is believed to disrupt ecosystems and the disturb the "competitive coexistence between predators and prey" (Sekercioglu, 2006, p. 468).

As noted, framing Saker exports in the treadmill of production framework has implications for wildlife exports as ecological destruction may facilitate species endangerment. Fig. 2 plots the trends in Saker exports between 1970 and 2015. Consistent with treadmill arguments, Saker exports are increasing over time. Thus, it can be argued that even when conservation increases within a nation, when it comes to trade "environmental concerns will remain subordinate to economic interests" (Hoffmann, 2004, p. 84). As a result, efforts to protect species will be over-ridden by economic expansion and interests such as Saker falcon commodification. Thus, treadmill ideology may lead to the exploitation of wildlife when it is profitable. In some instances, even conservation efforts to protect the Saker falcon from endangerment have been commodified by advertising the sale of coins made from precious metals and stone (<https://www.youtube.com/watch?v=h-29MQQsxDE>).

<sup>2</sup> Trapping Sakers is sometimes reported to be a highly lucrative business. Levin (2011) a Saker can cost \$75,000 in the illegal market. Galushin et al. (2000, p. 40–41) indicates that many estimates reported in the media are exaggerated and only serve to "provoke local people to rob falcon nests." Galushin (2004) estimates that the actual cost of a wild Saker in the illegal market is between \$2000 and \$3000 (see also van Kreveld, 2007).



**Fig. 2.** Trends in global saker exports (1975–2015)<sup>a</sup> and the estimated global saker population (1993–2013)<sup>b</sup>.

a. CITES export data (<https://trade.cites.org>).

b. Symes (2012).

Importantly, treadmill of production arguments critique the modernization proposition that new technology leads to expanded environmental protection and necessarily reduces environmental harm. In the case of Saker falcons, for example, a modernization argument might suggest that efforts to protect lands, reduce ecological withdrawals and additions, and employ efforts to bolster wild Sakers populations using technology (e.g., efficient artificial nesting). As illustrated in Fig. 2, however, there has been a long-term tendency for Saker exports to increase and the number of wild Sakers to decrease, contradicting the expectations of ecological modernization arguments. Noting the limitations of ecological modernization arguments, Clausen and Clark's (2005, 2008a, 2008b) empirical studies reject modernization arguments for fresh and marine water fish species.

Jorgenson (2006), specifically argues that the structure of international trade relationships creates unequal ecological exchanges between nations, and that exchange relationship promote ecological deterioration in less developed nations. Jorgenson (2006, 2009, 2012, 2016) has undertaken numerous tests of this Hypothesis, providing significant empirical support for these arguments. He also notes that trade export intensity, sometimes measured as a ratio of export gross domestic product relative to total gross domestic product, measures one dimension of international trade relationships. Moreover, Jorgenson argues that the global structure of international production and trade affects ecological consumption and generates adverse ecological impacts across nations (Jorgenson, 2012, 2016), that can include adverse biodiversity effects (Jorgenson, 2006). It is therefore possible, that the increased trade in and a declining population of falcons may be related to global trade and ecological exchange patterns, as well as to internal economic dynamics within nations. The treadmill of production and unequal ecological exchange perspective leads us to propose two hypotheses:

**Hypothesis 3.** As national income levels increase, falcon exports will increase.

**Hypothesis 4.** As global exports of goods and services increase, falcon exports will increase.

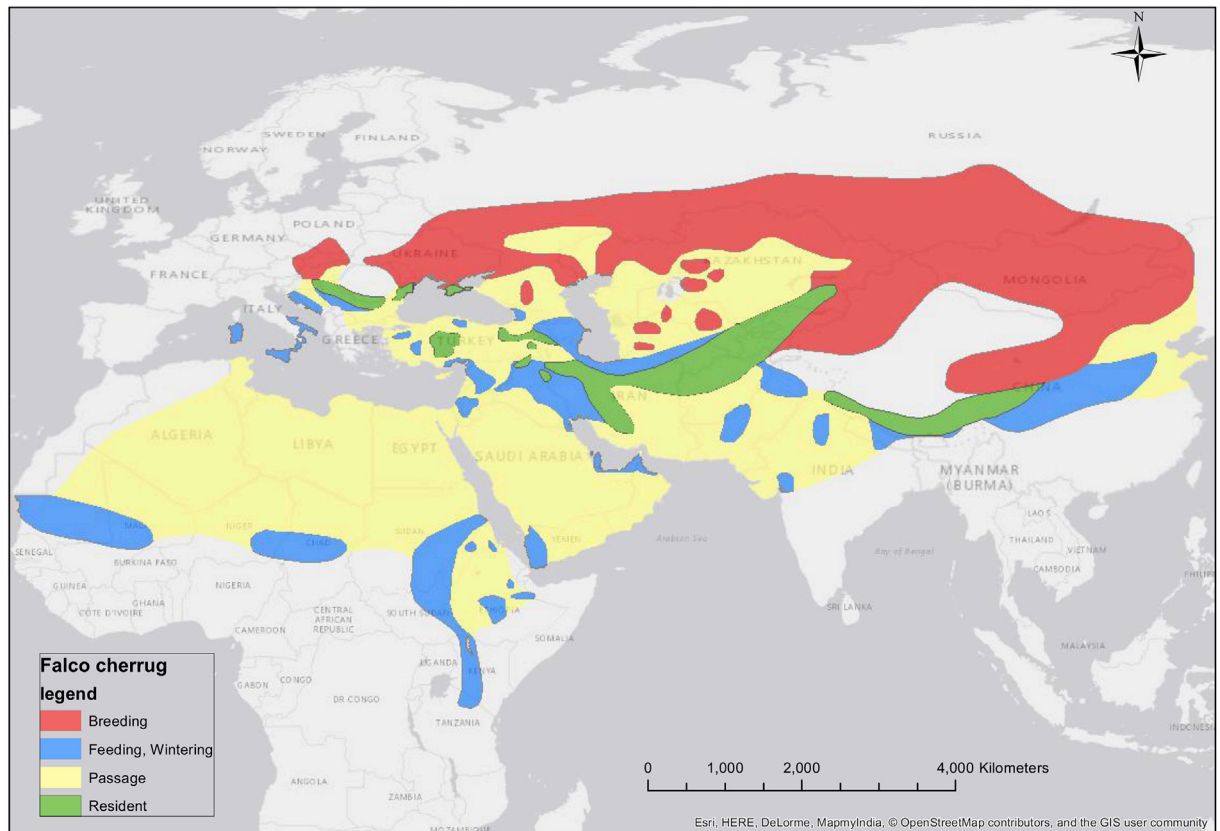
These hypotheses are measured using a nation's gross domestic product (#3) and the ratio of exports to gross domestic product (#4).

### 3. Overview of the Saker ecology, conservation efforts & global Saker Trade data

Saker falcons typically resides in grasslands ecologies across regions of Eastern Europe, Russia, Asia and parts of the Middle East (Eastham et al., 2000; Nemček et al., 2016).

Adult falcons live approximately 6 years, begin breeding around two to three years of age and produce up to six eggs annually (Castilla et al., 2010; Ellis and Ellis, 1997). Estimates suggest there may be as many as 28,000 breeding pairs of Sakers





**Fig. 3.** Distribution of saker falcons.

Data Source: <http://maps.iucnredlist.org/map.html?id=22696495>.

left in the world with as many as 5000 male/female pairs in China (Moshkin, 2010; see also <http://eol.org/pages/1049190/details>) though these figures are contested. Fig. 3 maps areas where Saker falcons reside, breed and migrate across the globe. As Fig. 3 indicates, Sakers are found in 54 countries, primarily in Eastern Europe, Russia, and Asia, and during migration and breeding seasons, in North Africa and the Middle East (<http://eol.org/pages/1049190/details>). Saker diet largely consists of squirrels, voles, hares and other birds (Watson and Clarke, 2000) (see Fig. 4).

It has long been recognized that Saker falcon populations are threatened by habitat destruction and the rising global popularity of falconry (Baumgart, 1994). Interest in falconry has led to the increasing international trade of these raptors as well as calls to end their export. IUCN Red List of Endangered Species (2017, p.1) recognizes export as the major reason for the Saker population decline “by at least 50% over three generations.” Some of the largest declines have occurred in countries such as Uzbekistan and Kazakhstan (Kovács et al., 2014) but there is some variation in reported falcon population declines. For example, aggressive conservation efforts to protect the Saker in Hungary (where it is the national bird) may be contributing to its increasing population (Bagyura et al., 2004; Baumgart, 1994; Dixon, 2016).

Efforts to combat Saker population declines have taken a variety of approaches (Dixon, 2012). Captive breeding and artificial nests have been used to bolster Saker populations in several countries and there is a “Global Action Plan” for Saker conservation (Kovács et al., 2014; [http://www.cms.int/sites/default/files/document/SakerGAP\\_e.pdf](http://www.cms.int/sites/default/files/document/SakerGAP_e.pdf)). Moreover, increased pressure to protect and monitor the Saker has come from conservation groups such as the Russian Raptor Research and Conservation Network (<http://rrrcn.ru/en>) and the Royal Society for the Protection of Birds (<https://www.rspb.org.uk>). These and other conservation efforts are often praised for their ability to bolster Saker populations.

### 3.1. Saker falcon export data

We examine the global export of Saker falcons using the CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) Trade Database. The Trade Database is managed by the United Nations Environmental Programme's World Conservation Monitoring. Because most countries are signatories to CITES, the Trade Database represents the most extensive and largest data collection currently available on the sustainable use of wildlife. The CITES database holds records on trade for around 34,000 thousand wildlife species, and more than a million trade transactions are recorded in



**Fig. 4.** Image of Saker Falcon in Captivity.

By Rod Ward - Own work by the original uploader, Public Domain, <https://commons.wikimedia.org/w/index.php?curid=49183330>.

CITES annually. CITES aggregates trade data and uses it in their annual reports that aid in monitoring the Convention. The CITES Trade Database can be queried on its website ([www.cites.org](http://www.cites.org)).

One major purpose of the CITES database is to provide a summary of the wildlife trade between countries so that trends in trade can be monitored. Theoretically, CITES aids in conservation efforts by setting the rules for international trade in selected endangered species. Designated management authorities in each participating country rely on scientific experts to make decisions about the level of a country's exports. Management authorities issue trade permits that allow for wildlife trade under certain conditions (e.g., exporters must obtain specimens legally and show that they minimize injury during shipping). CITES lists endangered species in three appendices that guide the level of species protection. Appendix I provides the greatest level of protection because 'trade is permitted only in exceptional circumstances.' Appendix II provides for trade only if that trade does not threaten species survival. Appendix III requires export permits among members of the convention that have listed the species as endangered and therefore provides the least amount of protection. CITES lists the Saker falcon in Appendix II of the Convention, meaning that export permits are required by all countries that export Saker falcons.

CITES is not without criticism (Smith et al., 2010). For instance, it is not clear how appointed scientific authorities within nations make recommendations about CITES exports as they do not normally make the reasoning behind their decisions known. In addition, it is not clear whether these experts may be aware of the level of species extraction, especially in some nations where corruption is high (Smith and Walpole, 2005). Moreover, CITES only focuses on trade at the species level and does not promote sustainable use. Instead, CITES looks to limit unsustainable practices without directly supporting "on-the-ground enforcement" (Smith et al., 2010). While criticisms are largely based on conservation issues, not all trade is recorded in CITES and data on reported levels of imports and exports can be off by a factor of hundreds in some species (see, for example, Blundell and Mascia, 2005). Finally, illegal trade in wildlife is not recorded in CITES. Despite all these concerns, CITES can be considered the most comprehensive database available on the global Saker falcon trade.

#### 4. Methods: analytic strategy, sample & variables

To examine the four hypotheses derived above, we collected data on Saker exports and their potential theoretical drivers for nations that export Saker falcons. This section details our analytic strategy, sample and the variables used to examine our hypotheses.

##### 4.1. Analytic strategy

Theoretically, we are interested in trends in Saker exports within countries. To study these trends and their potential drivers we employed fixed-effects panel models based on longitudinal data (Kohler and Kreuter, 2009). The fixed-effects approach is theoretically appropriate because we are interested in social change within countries. Fixed effects regression allows for the investigation of Saker exports while controlling for any omitted time-invariant differences between nations.

**Table 1**Fixed effects coefficients predicting saker falcon exports in 57 countries, 1975 to 2015.<sup>a</sup>

	Model 1 Conservation	Model 2 Modernization /Treadmill /Unequal Exchange	Model 3 Saturated
Independent Variables	<i>b</i> (S.E.)	<i>b</i> (S.E.)	<i>b</i> (S.E.)
Ecological footprint	−2.98 (2.64)		−3.23 (2.57)
Protected Land (% all land)	−0.115 (0.380)		−0.627 (0.448)
Per Capita GDP (in thousands \$)		1.37* (0.691)	1.47* (0.742)
Per Capita GDP Squared		−0.0154 (0.00916)	−0.0136 (0.00989)
General Exports		1.74*** (0.361)	1.82*** (0.372)
Falcon Imports (lagged)	0.308*** (0.051)	0.291*** (0.045)	0.256*** (0.0494)
Population (in millions)	−0.570 (8.9)	−15.9 (8.89)	−13.9 (8.9)
Constant	44.9*** (12.9)	30.2* (13.4)	−17.6 (16.7)
N	646	646	646
R <sup>2</sup>	0.08 <sup>b</sup>	0.11	0.11

\**p* < .05, \*\**p* < .01, \*\*\**p* < .001 (two-tailed tests).<sup>a</sup> Not all countries collected Saker export data starting in 1975. See Appendix A for CITES ratification dates in each country.<sup>b</sup> R<sup>2</sup> is based on non-imputed models.

Coefficients that summarize the potential relationship between drivers and exports are estimated using the 'xtreg' command in Stata (Version 13). Our hypotheses are derived based on theorizing about important drivers of Saker exports within nations. However, we also assessed whether fixed-effects regression produces consistent estimates and is therefore the appropriate statistical technique (Greene, 2008). To this end we test for systematic differences in fixed and random (a potential alternative method) effects coefficients using the Hausman test (Greene, 2008). Under the Hausman test we reject the null Hypothesis (Chi-Square (df = 5) = 12.8; *p* < .05) and conclude that coefficients are dissimilar and that fixed effects are the preferable statistical approach (Table 1, Model 3). The fixed-effects model we use is specified as follows:

$$Y(ct) = X(ct) + \alpha(c) + \epsilon(ct); \text{ for } t = 1 \text{ to } T \text{ and } c = 1 \text{ to } N$$

Where *Y(ct)* is the dependent variable for the country 'c' at time 't', *X(ct)* is a 1 by *k* matrix of predictor variables, *α(c)* is the unobserved time-variant country effect, and *ε(ct)* is the error term.

#### 4.2. Sample

The sample consists of the 24 nations listed in Appendix A that are signatories to CITES and have exported at least 100 Saker Falcons between 1971 and 2015. This sample of nations is likely to represent most Saker exports. For instance, nations in Appendix A represent 97.7 percent of all Saker falcon exports recorded in the CITES database.<sup>3</sup> Moreover, only three export nations that fall within the global distribution of Saker Falcons in Fig. 3 are not CITES signatories (i.e., Turkmenistan, South Sudan and Western Sahara). All three are known to be Saker wintering areas. Both Turkmenistan and South Sudan are also

<sup>3</sup> A total of 57 countries that exported at least one Saker falcon between 1971 and 2015 are not included in the analysis. These 57 countries accounted for 920 Saker exports over 45 years. This represents an average of 0.36 falcons per country per year. These 920 Saker exports make up less than 2.5 percent of all Saker exports.



likely to serve as migration routes for the Saker (see Eastham et al., 2000; Kovács et al., 2014). Appendix A also includes information on the number of years included in the sample for each nation and the total exported Saker falcons during those years by nation.

#### 4.3. Variables

The variables used in the analysis are described below, and descriptive statistics for variables are found in Appendix B. Specifically, we examine two potential drivers of Saker exports that conform to the biological conservation perspective: the ecological footprint and protected lands. We examine directly the notion that national income (GDP) may lead to increasing or decreasing exports to assess treadmill of production and ecological modernization arguments. We also assess the unequal ecological exchange perspective using global exports of goods and services as a percentage of total GDP. Finally, we control for Saker imports and the population of the nation.

##### 4.3.1. Saker exports

The dependent variable is a count of the number of *living* (excludes eggs or raptor parts) Saker falcons a nation exports annually, from 1975 (the year of CITES ratification) through 2015. Because nations ratified CITES in different years, the number of years of available Saker export data vary across nations. These ratification dates are listed in Appendix A. Saker exports have increased between 1975 and 2015. The 24 countries in this analysis exported 27,185 Sakers from 1975 through 2015, with a mean of 39.51 per country per year (Std. Dev. = 77.98). These statistics correspond to previous literature on the increasing demand for Sakers for use in falconry.

##### 4.3.2. Ecological footprint

The first predictor of Saker falcon exports is the ecological footprint of nations. This variable follows a major premise in conservation biology that land use shapes species populations. Conservation biologists are concerned with the conversion of natural landscapes for human use and the impact those conversions have on wildlife populations. There are a significant number of studies that demonstrate that changes to landscapes through human causes such as clearing forests, agriculture, urban development are diminishing species populations (Sala et al., 2000). The ecological footprint is an aggregate measure of the consumption orientation of society, and indicative of whether consumption practices within a nation are ecologically sustainable. These consumption patterns are then compared against natural capital and services provided by the environment. Thus, consumption patterns within nations are used to estimate the land area (i.e., footprint) needed to meet the ecological services that humans demand. These calculations are measured on a per capita basis (<http://www.footprintnetwork.org/our-work/ecological-footprint/>).<sup>4</sup>

Drawing upon a conservation biology perspective we suggest nations that reduce their ecological footprint better protect their natural capital and ecosystem services. Therefore, CITES authorities are more likely to allow for Saker falcons to be exported under such circumstances. Consistent with our theoretical discussion and Hypothesis 1, we suggest that the *Ecological footprint* should be negatively correlated with *Saker exports* because conservation should increase the number of wild Sakers. That is, as the ecological footprint decreases through conservation efforts, Saker falcon exports will increase because they are more available. Data on the ecological footprint for each nation for each year are available from *Global Footprint Network* (<http://www.footprintnetwork.org/our-work/ecological-footprint/>).

##### 4.3.3. Protected lands

The percentage of protected land in each country was measured using data from *The World Database on Protected Areas* (WDPA) (<https://www.unep-wcmc.org/resources-and-data/wdpa>). WDPA is the most comprehensive database on protected lands currently available (UNEP-WCMC, 2017; [www.protectedplanet.net](http://www.protectedplanet.net)), and is often used in conservation research (e.g., Jenkins and Joppa, 2009). The database is run as a joint project between United Nations and the International Union for Conservation of Nature. Specifically, protected lands are those areas recognized as protected through “legal or other effective means to achieve the long-term conservation of nature” (UNEP-WCMC, 2017, p. 7). Unfortunately, protected lands are not measured annually. Thus, we obtain estimates of protected lands from the World Bank for the years 1991, 2000 and 2014 and estimate missing years using Stata multiple imputation (‘mi estimate’) command (Royston, 2004). As Hypothesis 1 suggests, *protected lands* and *Saker exports* should be positively correlated. That is, as the percentage of a nation's protected land area increases, exports of the Saker should increase as an extension of land conservation efforts.

##### 4.3.4. GDP per capita

As noted, economic development may be related to the Saker falcon trade either through modernization (i.e., the environmental Kuznet's curve) or as is suggested by the treadmill of production in a monotonically increasing function. To examine whether income is an important driver of exports we assess the relationship between falcon exports and gross domestic product (GDP) per capita (World Bank, 2017). GDP per capita represents the value of goods and service per person

<sup>4</sup> As nations develop so too do their global footprints increase. According to [footprintnetwork.org](http://www.footprintnetwork.org), the largest per capita global ecological footprints in the world belong to Luxembourg (13.1), Qatar (12.6), Australia (8.8), Trinidad and Tobago (8.8), Canada (8.8) and the United States (8.2).

and is often used as a measure of economic performance and as an indicator of development. To examine the notion of modernization using GDP per capita we look to see if it takes on a non-linear, inverted-U shape relationship with falcon exports. To examine this type of non-linear relationship it is necessary to include GDP per capita and GDP per capita squared models. Consistent with [Hypotheses 2](#) and [Fig. 1](#), if the coefficient of GDP per capita is positive and the coefficient for GDP per capita squared is negative, then there is empirical support for the inverted U-shape relationship and therefore the modernization perspective. That is, at lower levels of income an increase in GDP per capita would correspond to an increase in Saker exports while at higher levels of income an increase in GDP per capita would correspond to a decrease in Saker exports. If increasing levels of capitalist production under the treadmill perspective is a better explanation of Saker exports then GDP per capita should be positively related to *Saker exports* while *GDP per capita squared* will be unrelated to Saker exports.

#### 4.3.5. Exports

Next, we consider whether the general reliance on exports, as a percentage of a nation's GDP, increases Saker exports. Here, the question is whether growth in general exports of goods and services generates economic pressure to increase Saker exports. This variable comes from the [World Bank \(2017\)](#). The suggestion that exports are related to a nation's biodiversity loss is consistent with [Jorgenson's \(2006\)](#) argument about the structure of international trade relationships and the unequal ecological exchange between nations. Thus, as export intensity measured as a percentage of GDP increases, falcon exports should also increase ([Hypothesis 4](#)) because the global structure of trade can have adverse biodiversity impacts.

#### 4.3.6. Saker imports and national population

Finally, we consider two additional variables as predictors of Saker exports: Saker imports and country population. First, we include a lagged measure of Saker imports to determine if they predict falcon exports in the following year. While Saker falcons may be imported into a country for a variety of reasons, imports of falcons can bolster domestic populations that can then be exported. Thus, imported falcons may simply serve to increase the supply of falcons available for subsequent export. Data on falcon imports were obtained from CITES. Finally, we also use a nation's population as a traditional indicator of Saker exports, given that an increase in the population means there are more potential people to trap Saker falcons or take Saker chicks and eggs from the nest. Population data is obtained from the [World Bank \(2017\)](#).

## 5. Results

The results of our hypotheses tests are presented in [Table 1](#) which report the unstandardized fixed-effects regression coefficients and corresponding standard errors for Saker exports in 24 nations between 1975 and 2015. For each model, we report R-Squared within that summarizes the overall goodness of fit. The variables in [Table 1](#) are divided into three categories for ease of interpretation and comparison. Model 1, [Table 1](#) reports the regression results for 'conservation' variables (*ecological footprint*, *protected lands*) and controls (*Saker imports* and *population*). Model 2, [Table 1](#) reports results for *GDP per capita*, *GDP per capita squared*, *exports* and controls. Model 3, [Table 1](#) reports results where for all variables in one model.

One advantage of the fixed effects models in [Table 1](#) is that they can be easily interpreted. For any given nation, as the value of independent variables change across time by one unit, falcon exports increase or decrease by  $b$  units. Because falcons are measured as the number of birds, coefficients can be understood as an increase or decrease in the number of falcons. For example, Model 1 ([Table 1](#)) suggests that each additional Saker imported in the previous year results in 0.31 Sakers exported the next year. Put another way, for every 3.2 falcons a nation imports in one year, it will export 1 additional Saker falcon in the following year ( $b = 0.31$ ;  $p < .01$ ). This result implies that efforts to supply a nation with Saker falcons through imports lead to greater falcon exports. Importantly, neither the ecological footprint nor the percentage of protected lands is associated with exports and therefore there is little support for [Hypothesis 1](#). That is, more responsible land use (i.e., the lower the ecological footprint) is not associated with an increase in Saker falcon exports.

Model 2 ([Table 1](#)) shows little support for the modernization Hypothesis ([Hypotheses 2](#)) as *GDP per capita* and *GDP per capita squared* are not (together) statistically significant in that model. There is, however, support for the treadmill of production perspective as *GDP per capita* (alone) is significant in Model 2 ([Table 1](#)) as [Hypothesis 3](#) suggests. For example, a \$1000 increase in per capita GDP is associated with 1.37 ( $p < .05$ ) Saker falcon exports. Finally, there appears to be support for unequal ecological exchange ([Hypothesis 4](#)). That is, as the export of goods and services increase, the export of Saker falcons also increases. Specifically, a one percent increase in the overall level of exports of goods and services corresponds to 1.74 ( $p < .001$ ) more Saker exports over time. Thus, a nation's reliance on the global economy appears to influence the export of this endangered species.

The fully saturated model (Model 3, [Table 1](#)) replicates the findings in Models 1 and 2. That is, the coefficient and standard errors for exports and GDP per capita change very little. The consistency in results suggests there is considerable support for treadmill of production and unequal exchange in explaining falcon exports.

## 6. Discussion & conclusion

There has been a significant notable decline in the global Saker falcon population. The global export of these falcons has been noted as a significant cause of their decline and lead to their listing of 'endangered' on the *Red List of Threatened Species*. The present analysis has examined the drivers of Saker exports using CITES data drawing upon four major theoretical

frameworks: conservation biology, ecological modernization, treadmill of production and unequal exchange. Our analysis is the first of its kind to be carried out for nations exporting these falcons. To examine the important drivers of Saker exports we use fixed-effects regression analysis. That analysis suggests that conservation related efforts within nations—such as reducing the ecological footprint—appear to matter little with respect to exports. That is, general conservation efforts do not have much impact on the export of environmental products such as Sakers. As a result, we suggest that something else is driving decisions about exports. In this analysis we emphasize that there may be important links between the ecology and economy. Thus, while it is still plausible that more specific Saker conservation efforts increase the availability of Saker falcons for export (see for example [Clarke and Rolf, 2013](#); [Pires and Clarke, 2011](#); [2012](#)), exports are in part driven by treadmill policies.

The implications of our findings for conservation efforts and biodiversity are important to consider. First, those findings suggest that general conservation efforts do not necessarily protect species from all forms of harm when it comes to exports of species and the economic drivers of those exports. In the present case, falcon exports increased in a treadmill fashion within nations as a function of GDP. In that context, efforts to promote conservation efforts are likely insufficient, and must be bolstered with more targeted efforts to limit the collection of wild species for trade. In theory, such policies should be linked to CITES permits for trade in Saker falcons, and export limits and fees in individual nations. Clearly, export limits and fees are not sufficiently strict to discourage falcon exports. It is certainly understandable that CITES authorities may allow a greater number of Saker falcons to be exported when a nation appears to adequately protect falcons through conservation efforts. That overall approach, however, does not appear to have halted the global decline of Saker falcons. Thus, like others, we suggest that the policies surrounding the trade of endangered and threatened species should be revisited ([Morgan and Chng, 2017](#)). This observation is consistent with those made by critical scholars who note that CITES essentially provides legal grounds for the trafficking of endangered species in a way that may lead to their eventual decline and extinction ([Sollund, 2011](#)).

Our findings help us formulate two suggestions for a way forward. First, as we point out, Saker exports should be decelerated in all nations because the pressure to increase exports will only continue to grow as income and trade expand. And, while it may not be possible to end illegal Saker trade (even by emphasizing deterrent messages), it is *possible* to begin to reduce those legal Saker exports now to head off any future population crises that may emerge with rising national income and increasing global trade. If, as we suspect, legal exports are contributing to diminishing populations this action should serve to ease the decline of the global Saker population. Second, while we recognize that conservation education is not always the solution to ecological problems ([Hungerford and Volk, 1990](#)) it could prove useful in nations that import high numbers of Saker falcons. We stress that such programs should focus on environmental empowerment by emphasizing general conservation citizenship and not just focusing on falcon's and falconry (see also [Schwartz, 2013](#)). Nevertheless, decades of widespread pro-falconry socialization are likely to impede such efforts to change behavior ([Kollmuss and Agyeman, 2002](#)). Still, it is our hope that such programs could build personal investments in conservation behavior that are likely to reduce the popularity and participation in falconry and therefore lower the demand for Sakers exports over the long-term.

While our study is the first to examine the relationship between general conservation efforts, income, general exports and Saker exports, it is not without limitations. First, our conservation variables are loose indicators of the concept “conservation.” Certainly, an increase in protected areas (though not significant here) and a reduction in the ecological footprint is likely to have positive consequences for biodiversity and species health, but short of operationalizing exactly what these benefits are for Saker falcons makes it difficult to capture a true estimate of the relationship between conservation efforts and Saker exports. Second, we recognize that there are problems with CITES estimates. What is recorded in CITES only represents known Saker falcon exports, and excludes illegal trade. How the addition of poaching data, for example, would change the relationships discovered here is open for further investigation. Third, wildlife such as the Saker falcon does not necessarily adhere to national boundaries. Thus, while conservation efforts may be measured within nations it is unlikely that they impact only those nations as seasonal migration patterns of Sakers can extend over several nations. Thus, we recommend that future studies examine how migration may relate to trade patterns, which also has implications for Saker falcons.

In the end, we suggest that it is widely recognized that human activities have unprecedented effects on wildlife. Effective policies for controlling the adverse consequences of human behavior on wildlife are still under construction. Our results imply that conserving the Saker falcon within a nation by limiting its exports is hampered by continuing economic expansion and high levels of trade. As a result, conservation efforts appear to be offset by economic conditions that drive trade—something we suggest needs to change.

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## Appendix A. Countries in the analyses by year ratified in CITES, number of years of data and number of Saker falcons exported

Country	Year Ratified	No. Years	No. Saker Falcons Exported
Austria	1981	35	1014
Belgium	1984	32	183
Canada	1975	41	194
China	1981	35	486
Czech Republic	1993	23	197
Germany	1976	40	2698
Jordan	1979	37	121
Kazakhstan	2000	16	1180
Kuwait	2002	14	1334
Mali	1994	22	225
Mongolia	1996	20	3501
Morocco	1976	40	534
Netherlands	1984	32	103
Pakistan	1976	40	4369
Qatar	2001	15	520
Russian Federation	1992	24	2790
Saudi Arabia	1996	20	3245
Spain	1986	30	265
Sudan	1983	33	232
Syrian Arab Republic (Syria)	2003	13	538
Tunisia	1975	41	549
United Arab Emirates	1990	26	1983
United Kingdom	1976	40	646
Uzbekistan	1997	19	278
Total	—	688	27,185

## Appendix B. Descriptive Statistics (N = 688)

Variable	Mean	Std. Dev.	Minimum	Maximum
<i>Saker exports</i>	39.51	77.98	0	454
<i>Ecological footprint</i>	4.52	3.51	0.55	15.04
<i>Protected lands</i> (% of all lands)	10.15	8.99	0.09	38.46
<i>Per capita gross domestic product</i> (in thousands of \$)	15.290	17.353	0.193	94.944
<i>Saker imports</i> (lagged)	32.21	91.10	0	816
<i>Population</i> (millions of people)	0.94	2.63	0.01	13.71
<i>Exports</i>	37.21339	18.83453	3.335026	101.0223

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